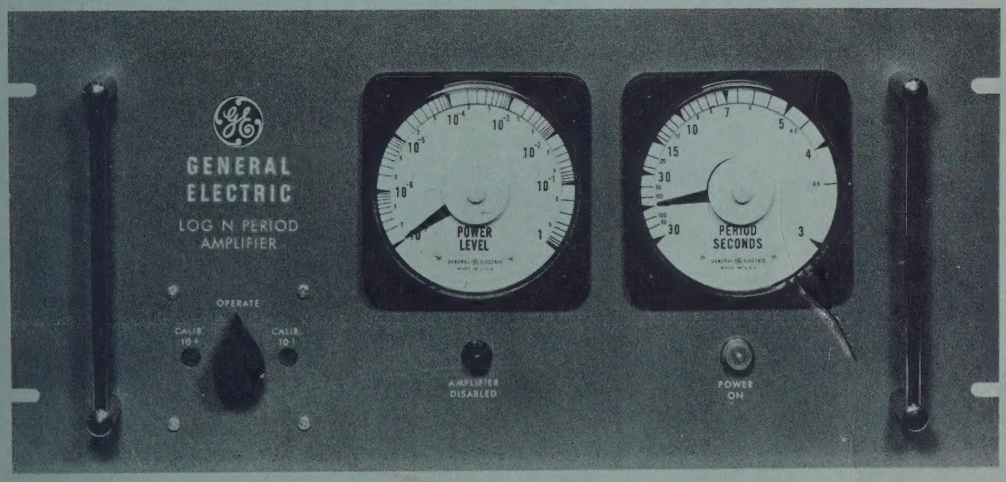
A.N. IVERSON
1713-D

GEI-59325

INSTRUCTIONS

LOG N PERIOD AMPLIFIER

Catalog Numbers 655C910G1, G2



MP MASTER
MA32631

GENERAL ELECTRIC

NOTICE

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

GEI-59325

OPERATION AND MAINTENANCE INSTRUCTIONS

For

GENERAL ELECTRIC

LOG N And PERIOD AMPLIFIER

Catalog Numbers

655C910G1
655C910G2

November 27, 1959

ATOMIC POWER EQUIPMENT DEPARTMENT

GENERAL ELECTRIC

SAN JOSE, CALIFORNIA

TABLE OF CONTENTS

Page

SECTION I DESCRIPTION

1.1 General.....1-1
1.2 Construction.....1-2
1.3 Application.....1-2
1.4 Specifications.....1-2

SECTION II THEORY OF OPERATION

2.1 General.....2-1
2.2 Circuit Description and Operation.....2-1

SECTION III OPERATING INSTRUCTIONS

3.1 Unpacking.....3-1
3.2 Installation.....3-1
3.3 Operating Controls.....3-1
3.4 Connections.....3-3
3.5 Operating Procedures.....3-4
3.6 Precautions.....3-4

SECTION IV MAINTENANCE INSTRUCTIONS

4.1 General.....4-1
4.2 Periodic Maintenance.....4-1
4.3 Calibration Procedure.....4-1
4.4 Calibration Instruments.....4-3
4.5 Trouble Shooting.....4-3

SECTION V

REPLACEABLE PARTS LIST.....5-1
MANUFACTURER'S CODE LETTERS.....5-7

SECTION I

DESCRIPTION

1.1 General

The General Electric Log N and Period Amplifier is designed for nuclear reactor neutron measurement, and control in the intermediate range between startup and full power operation. The amplifier indicates relative power level and the reactor period in seconds from the current signal of a neutron-sensative ion chamber. It generates a period alarm and trip signal when the period signal exceeds a pre-set trip point.

Two types of Log N and Period Amplifiers are available. The catalog numbers of these units are 655C910G1 and 655C910G2. A Log N meter and a Period meter are mounted on the 655C910G1 unit, as shown on the front cover. The 655C910G2 unit is designed for remote location of these meters and therefore there are no panel-mounted meters on this unit. Remote meters are furnished with this unit for the user to mount in a remote panel. The electronic circuits and functions of the two types of units are identical. Discussions concerning operation and maintenance presented in this manual pertain to both units.

1.1.1 Log N Power Level Meter

Operation of a nuclear reactor requires that the neutron flux (or fission rate) be known over a wide range. The Log N meter performs this function by measuring ionization current over seven decades of power level. Basically, it is a micromicroammeter utilizing an operation d-c amplifier with logarithmic feedback and fast response. The Log N meter measures ionization current in the range of 10^{-11} to 10^{-4} amperes, and indicates power level on a logarithmic indicating meter.

1.1.2 Period Amplifier

Period is the interval in which power level is changing by a factor of 2.718. Since the power level may increase exponentially, it is important to be able to trip the nuclear reactor when the rate of power increase becomes too fast. The period function of the Period Amplifier is performed by differentiating the voltage signal indicating the time derivative of the logarithm of the neutron flux. Period indication is from minus 30 seconds to infinity to plus 3 seconds. Trip and alarm adjustment are from plus 30 to plus 3 seconds.

1.2 Construction

The General Electric Log N and Period Amplifier is a ruggedized industrial instrument designed for continuous service where high reliability is of importance to the user. It is housed in a 8-3/4 inch by 19 inch front panel with a 13 inch deep chassis for standard rack mounting. (See Figures 1-1 and 1-2 for mounting dimensions.) High quality epoxy-resin etched circuitry is employed, and permium quality electronic tubes are used. The unit contains its own regulated power supplies. Figures 1-3 through 1-6 show parts arrangement on the amplifier and power supply etched circuit boards.

"Chimney" type construction is used to promote interior component cooling. The indicating meters are the DB-18 switchboard type with 7.1 inch scale length and 250 degrees rotation for easy readability. The cable connectors which are furnished permit ready connection into reactor control, recording, or remote indicating circuits. The 115 volt a-c supply cable is furnished to facilitate ease of user installation.

The Log N meter is calibrated by turning an OPERATE-CALIBRATE switch to two test positions. This places a calibration current on the amplifier input equivalent to 10^{-6} and to 10^{-1} on the logarithmic meter. Screwdriver type adjustment potentiometers are used for calibration.

1.3 Application

The Log N and Period Amplifier is used with gamma compensated ion chambers to measure and indicate reactor power level over seven decades; and to indicate reactor period and trip when the period becomes too short. Its alarm and trip output can be connected into reactor protective and alarm circuits.

It may also be used as a log micromicroammeter for radiation monitoring, process monitoring, and dosimetry work.

When the Log N and Period Amplifier is used with a compensated ion chamber, the General Electric High Voltage Power Supply, Catalog No. 693C343G2, is recommended. This unit is a dual-power supply with simultaneous positive and negative voltage outputs. More than one compensated ion chamber may be supplied from each power supply.

1.4 Specifications

1.4.1 Log Level

Range:	10^{-11} to 10^{-4} amperes	
Scale:	Seven evenly spaced logarithmic decades, calibrated in power level, 10^{-7} to 1.	
Accuracy:	10^{-10} to 10^{-5} amperes	Ratio of true to observed reading greater than 0.85 and less than 1.175

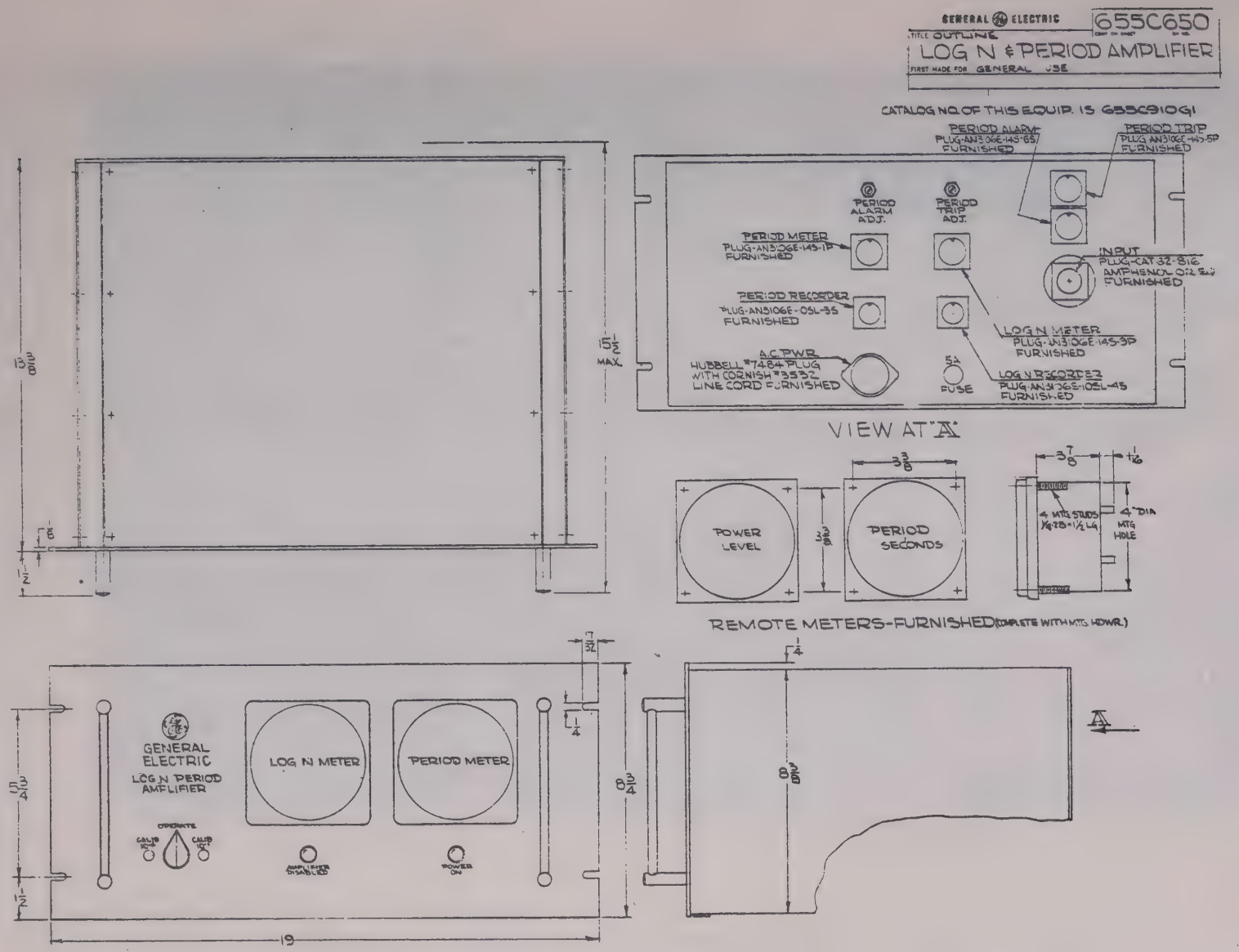

GENERAL ELECTRIC
655C650
TITLE OUTLINE
LOG N & PERIOD AMPLIFIER
FIRST MADE FOR GENERAL USE
CATALOG NO. OF THIS EQUIP. IS 655C910G1
PERIOD ALARM
PLUG-AN3106E-14S-6S
FURNISHED
PERIOD TRIP
PLUG-AN3106E-14S-5P
FURNISHED
PERIOD ALARM ADJ.
PERIOD TRIP ADJ.
PERIOD METER
PLUG-AN3106E-14S-1P
FURNISHED
INPUT
PLUG-CAT 32-816
AMPHENOL 61-2
FURNISHED
PERIOD RECORDER
PLUG-AN3106E-10SL-3S
FURNISHED
LOG N METER
PLUG-AN3106E-14S-3P
FURNISHED
A.C. PWR
HUBBELL #7484 PLUG
WITH CORNISH #353C
LINE CORD FURNISHED
5A
FUSE
LOG N RECORDER
PLUG-AN3106E-10SL-4S
FURNISHED
VIEW AT "A"
POWER LEVEL
PERIOD SECONDS
4 MTG STUDS
4" DIA MTG HOLE
REMOTE METERS-FURNISHED (COMPLETE WITH MTG HDWR.)
GENERAL ELECTRIC
LOG N PERIOD AMPLIFIER
LOG N METER
PERIOD METER
OPERATE
CALIB SET
AMPLIFIER DISABLED
POWER ON
19

FIGURE 1-2

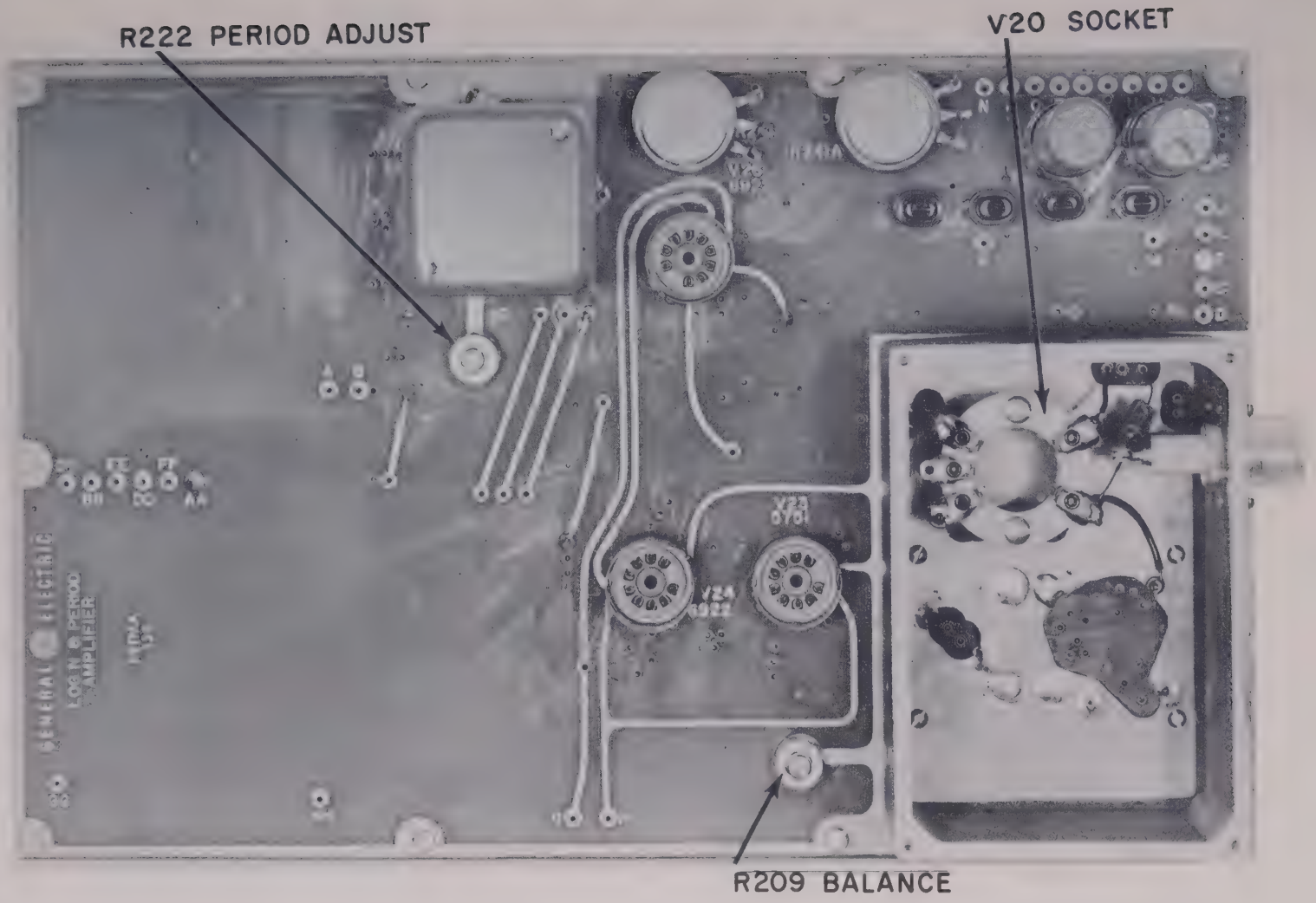


FIGURE 1-3 LOG N AND PERIOD AMPLIFIER CIRCUIT BOARD
TOP VIEW

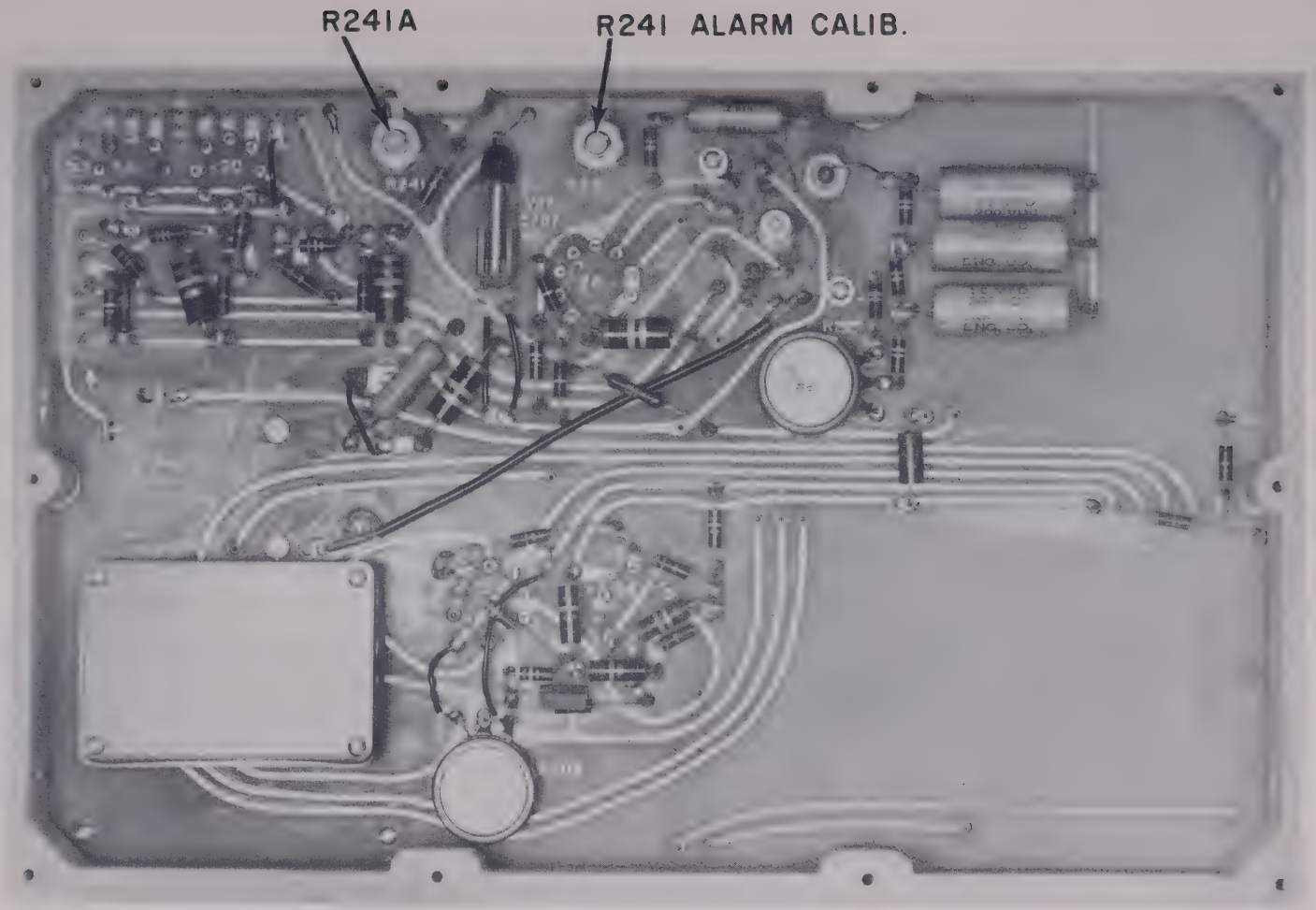


FIGURE 1-4 LOG N AND PERIOD AMPLIFIER CIRCUIT BOARD
BOTTOM VIEW

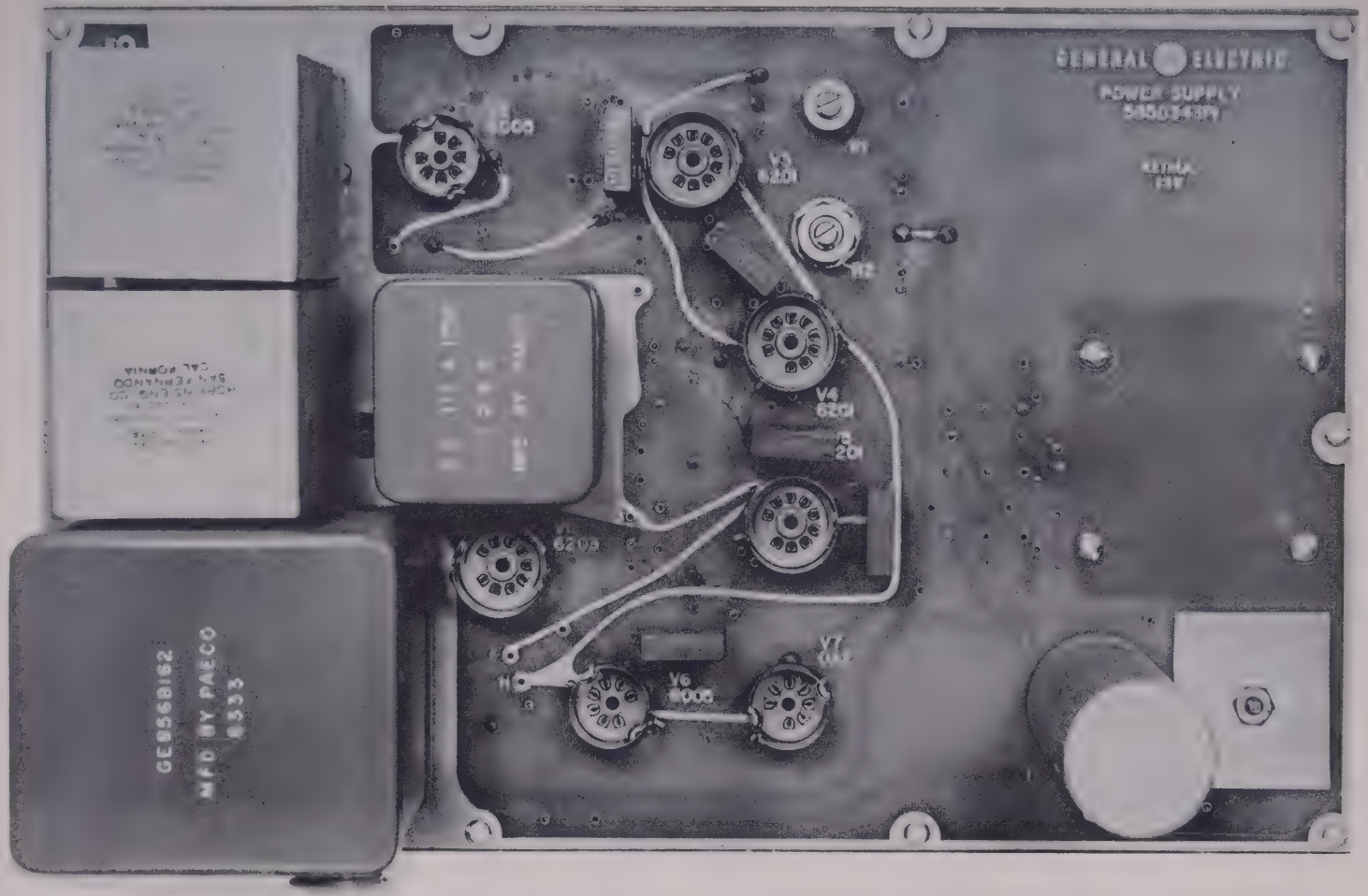


FIGURE 1-5 POWER SUPPLY ETCHED CIRCUIT BOARD
TOP VIEW

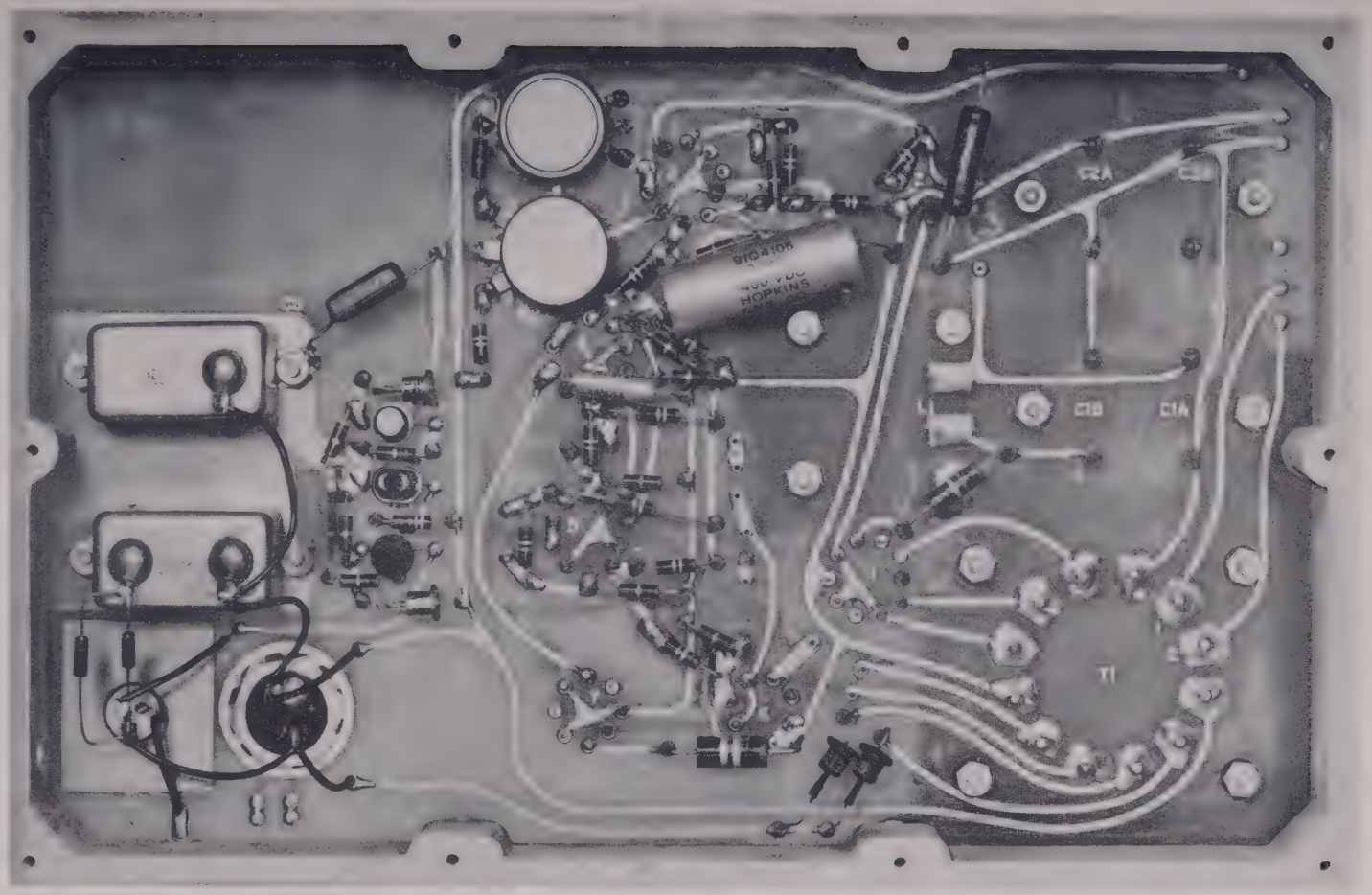


FIGURE 1-6 POWER SUPPLY ETCHED CIRCUIT BOARD
BOTTOM VIEW

Accuracy: (Continued)	10^{-11} to 10^{-10} and 10^{-5} to 10^{-4} amperes	Ratio greater than 0.7 and less than 1.4
Response Time:	One millisecond or less from 10^{-9} to 10^{-4} amperes with 2,000 MMFD cable capacity loading the input. 10 milliseconds at 10^{-10} amperes, 100 milliseconds at 10^{-11} amperes	

1.4.2 Period

Range:	Minus 30 seconds to infinity to plus 3 seconds
Scale:	Inverse calibration--minus 30 seconds to infinity to plus 3 seconds
Drift:	Less that ±2% at 3 second period
Accuracy:	Reciprocal of observed period will be within ±0.005 of the reciprocal of the ture period
Set Points:	Rear chassis, screwdriver locking adjustments variable over 30 to 3 second range
	Period alarm
	SPDT 2 ampere, 115 V a-c relay contacts
	Period trip
	SPDT 2 ampere, 115 V a-c relay contacts

1.4.3 Meters

Front panel, type DB-18, 7.1 inch 250 degrees scale for Catalog No. 655C910G1. Remote DB-18 meters are furnished for user to mount with remote unit, Catalog No. 655C910G2.

1.4.4 Outputs

Remote Meters:	0 to 1 ma d-c for both Log N and Period
Remote Recorders.	0 to 1 ma d-c or 0 to 10 mv d-c for both Log N and Period
Period Alarm:	SPDT 2 ampere, 115 V a-c
Period Trip:	SPDT 2 ampere, 115 V a-c

1.4.5 Power Requirements

115 V ±10%, 50/60 cycles, 60 watts

1.4.6 Fuse

5 ampere, mounted on rear panel

SECTION II

THEORY OF OPERATION

2.1 General

The General Electric Log N and Period Amplifier consists of five principal circuits designated as follows:

1. Power Supply
2. Logarithmic Amplifier
3. Period Amplifier
4. Period Alarm
5. Period Trip

The theory of operation and detailed descriptions of these circuits are presented in the following paragraphs.

2.2 Circuit Description and Operation

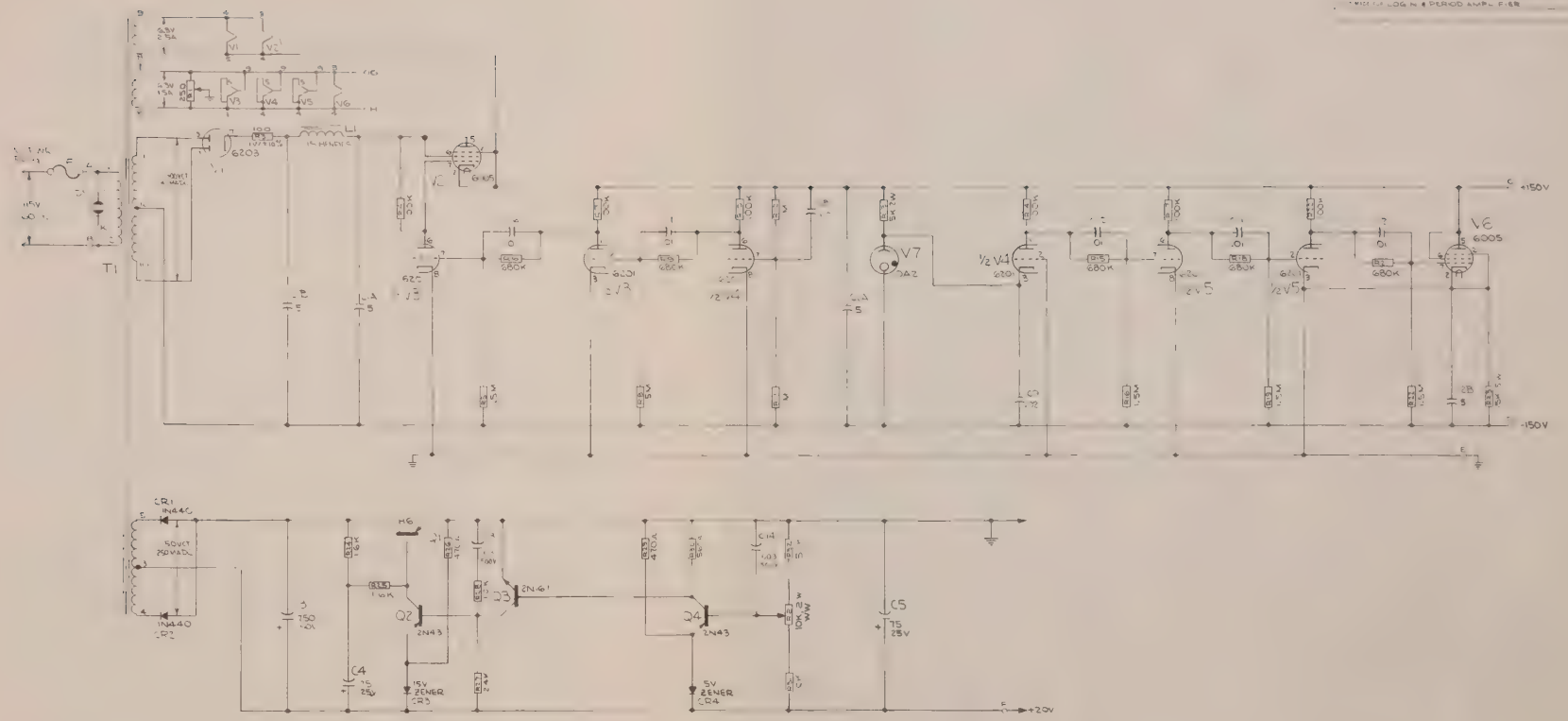
2.2.1 Power Supply

The power supply is comprised of two circuits: one supplies 150 volts plus and minus, the other circuit supplies plus 20 volts. Both power supply circuits are regulated for line and load variations. Refer to Figure 2-1, elementary circuit diagram and Figures 1-5 and 1-6 for physical placement of power supply parts.

2.2.1.1 Plus and Minus 150 Volt Supply

The two 150 volt supplies are fed from a common source. Winding 10,11, 12 on transformer T1 supplies a nominal 900 volts a-c to full-wave rectifier V1. A Pi-section filter composed of L1, C1A and C1B filters the power ahead of the regulator section. The output of the filter is applied to both the plus and minus 150 volt supplies.

Two regulating amplifiers are used in the circuit. One amplifier, which consists of 1/2-V4, V3, and V2, monitors the plus and minus buses and keeps them at equal potentials above and below ground. Equal resistors, R11 and R12, serve as a volgage divider with the center point connected to the control grid (point 7) of V4. The cathode of V4 (point 8) is tied to ground. If the two buses are not of equal (plus and minus) potential, the error signal is amplified and applied to series regulator V2 in the proper sense to restore equality. The interstage coupling utilizes phase-lead networks to improve the high frequency gain of the amplifier. A typical phase-lead network is C7, R9, and R8.



NOTES:
1. ALL RESISTORS ARE 1/2 WATT, ± 10% UNLESS OTHERWISE NOTED
2. CAPACITOR VALUES ARE IN MFD. & WORKING VOLTAGE IS 250 V DC UNLESS OTHERWISE NOTED.

FIGURE 2-1

The second amplifier, consisting of 1/2-V4, V5, and V6, monitors the negative bus, compares it to the gas reference tube V7, and regulates the negative bus to a nominal 150 volts.

The circuit may best be understood by referring to the simplified schematic of Figure 2-2. The total current of the system is conducted by V2. After supplying the voltage dividers and amplifiers, current i_1 remains for the load and the shunt regulator V6. The current i_2 passes through the shunt regulator V6, and current i_3 passes through load No. 1. Current i_4 passes from ground to the -150 volt bus through R23. Current i_5 passes through load No. 2. The following relationship must exist at all times:

$$i_1 = i_6 = i_2 + i_3 = i_4 + i_5 \quad \text{or} \quad i_2 = i_4 + (i_5 - i_3)$$

The reference amplifier controlling V6 regulates current i_2 to satisfy the above equation.

2.2.1.2 Plus 20 Volt Supply

The plus 20 volt power supply originates at winding 3, 4, and 5 on transformer T1 which provides a nominal 50 volts a-c. The a-c source is rectified by diodes CR1 and CR2 and smoothed by capacitor C3.

The regulation is accomplished by amplifier stages composed of transistors Q4, Q3, and Q2, which control a series regulator transistor Q1. The supply is referenced to a 15-volt reference diode, CR4. The error signal is applied to the base of transistor Q4 from a voltage divider composed of resistors R31, R2, and R32. Potentiometer R2 is used to adjust the output voltage.

A sudden decrease in load or increase in line voltage causes an increase in output voltage. This increased output voltage results in a decreased base current of transistor Q4 which in turn decreases the base current of transistors Q3, Q2, and Q1. The decrease in base current to transistor Q1 decreases the current supplied to the load, causing the voltage to return to normal. A decrease in output voltage initiates action in the opposite sense to restore the output voltage to normal. Thus, the supply is regulated for a variation in either line voltage or load.

2.2.2 Logarithmic Amplifier

The logarithmic amplifier, shown in elementary form in Figure 2-3, is a balanced d-c amplifier composed of tubes V20, V21, V22, V23, and V24. The input tube V21 and its balance tube V22 are electrometer tubes. The diode V20 is connected in the negative feedback path from the output of the amplifier to the control grid (point 1) of V21. This diode determines the logarithmic characteristic of the amplifier.

In operation, a positive current, (a current which would flow with a positive voltage applied), is supplied to the input at J8. An

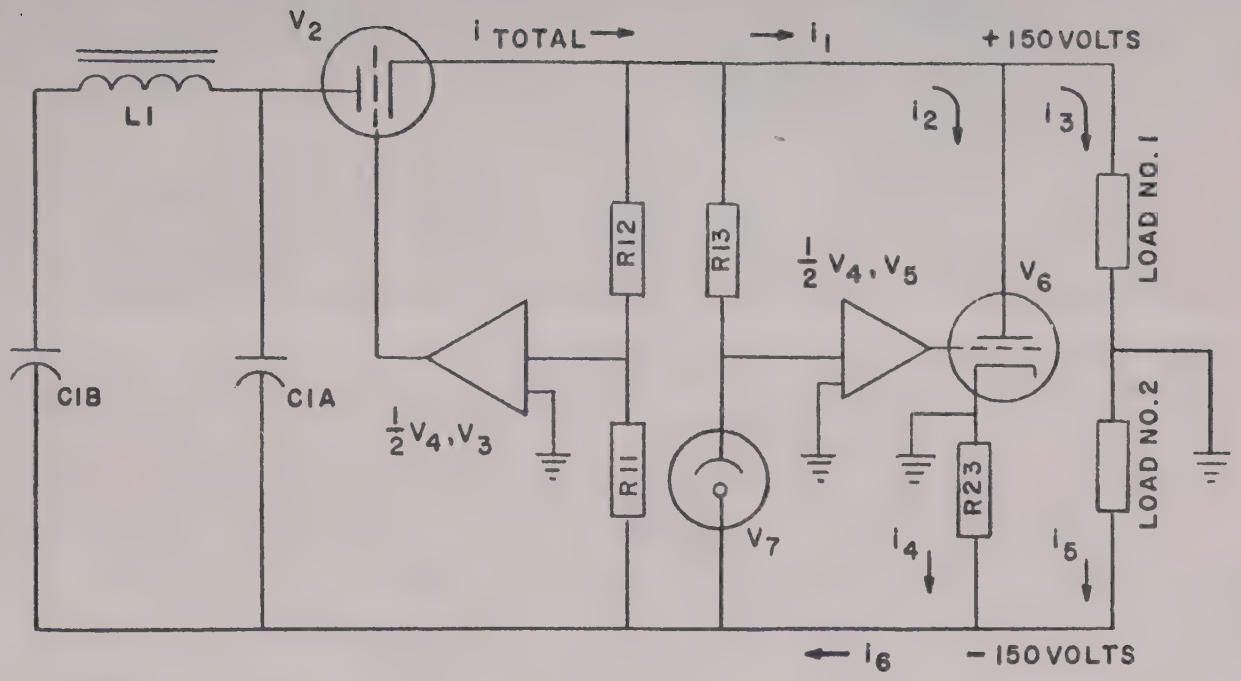


FIGURE 2-2

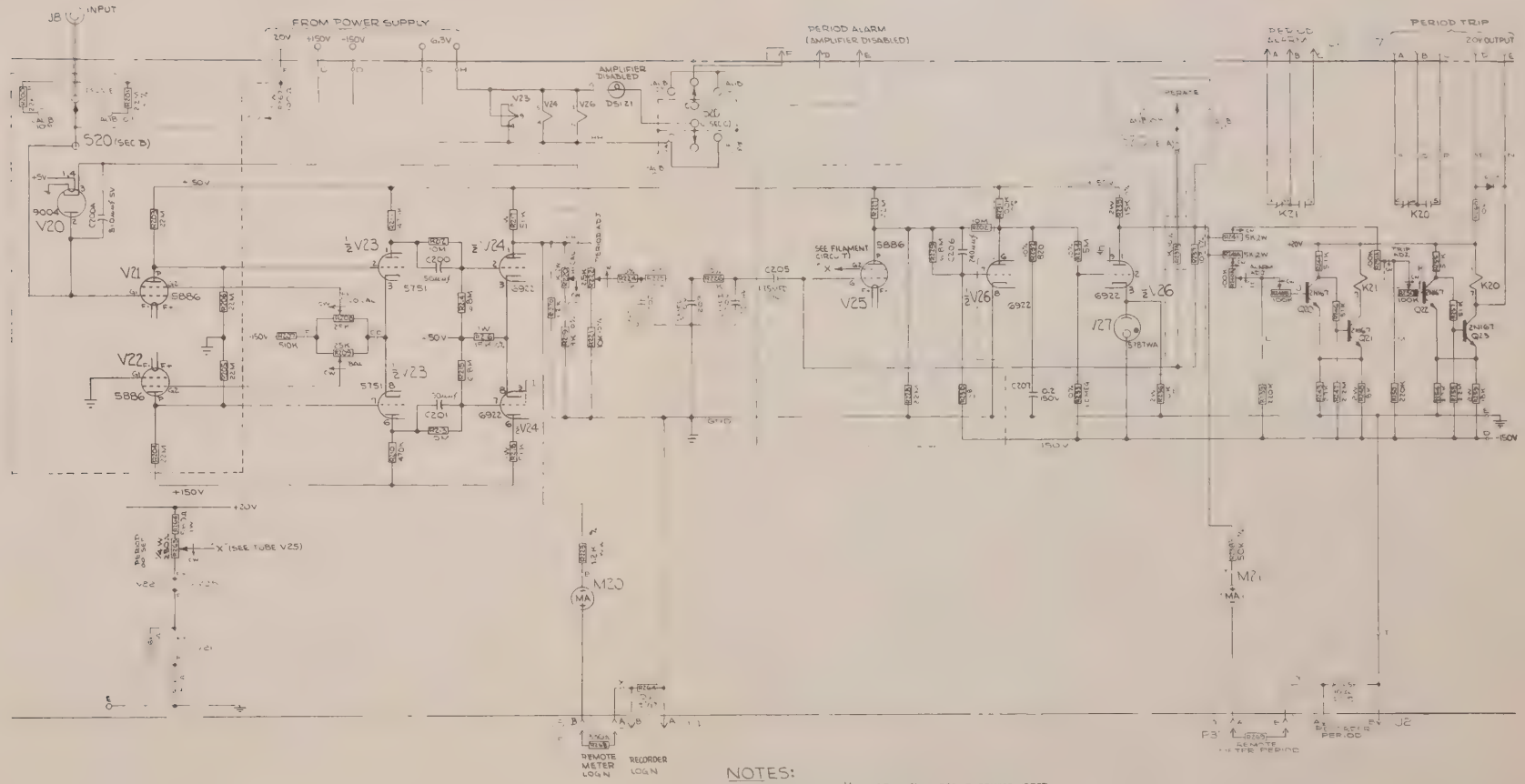
SCHEMATIC DIAGRAM
POWER SUPPLY REGULATING AMPLIFIER

GENERAL ELECTRIC 585D339

TITLE ELEM DIAG

LOG N & PERIOD AMPLIFIER

FOR MASTER GENERAL USE



NOTES:

1. ALL RESISTORS ARE ½ WATT ± 5% UNLESS OTHERWISE NOTED.
2. CAPACITOR VALUES ARE IN MFD & WORKING VOLTAGE IS 250 VDC UNLESS OTHERWISE NOTED.
3. RELAY SHOWN IN ENERGIZED POSITION & ARE DE-ENERGIZED TO TRIP

FIGURE 2-3

amplified negative going signal is applied to the point 2 control grid of V23, a positive going signal to the point 2 control grid of V24, and a negative going signal appears at the output, which is the tap of R220. This negative voltage is fed back through V20 in opposition to the input.

A diode operating in the negative bias region is logarithmic; that is, the voltage from plate to cathode is expressed by the following relationship:

$$e_b = K_1 \ln i + K_2$$

Where: e_b = instantaneous plate voltage

i = instantaneous plate current

K_1 = a proportionality constant

K_2 = a bias constant

Because the voltage across the diode is nearly equal to the amplifier output voltage and the current through the diode is equal to the input current, the following relationship exists:

$$e_{out} = K_1 \ln i_{in} + K_2$$

Where e_{out} = instantaneous output voltage

i_{in} = instantaneous input current

These relationships show that the output voltage is logarithmically proportional to the input current. A logarithmic scale has no zero. Resistors R200 and R201 provide calibration currents at two discrete points corresponding to the 10^{-6} and 10^{-1} points on the scale, or 10^{-10} and 10^{-5} amperes, respectively. The regulated 20 volt supply is the power source for this current.

The amplifier is balanced by adjusting potentiometer R209 which varies the voltage on the point 2 screen grid of V22. The low calibration adjustment is made with potentiometer R208 which varies the voltage on the point 2 screen grid of V21. The high calibration adjustment is made with potentiometer R220 which varies the feedback of the amplifier and thus the gain.

The filaments of tubes V20, V21, and V22 are supplied from the regulated 20 volt power supply to minimize drift and hum pickup. The amplifier is balanced with common cathode resistors to stabilize for ambient temperature changes and drift.

The output of the amplifier is fed to meter M20, to a remote meter connection, to a recorder output, and to the period amplifier.

2.2.3 Period Amplifier

The period amplifier is a high gain operational amplifier connected as a differentiator. The input tube V25 is an electrometer. The input

is followed by one stage of gain and a cathode follower in tube V26. Capacitor C205 is the differentiating capacitor and R237 is the feedback resistor. A three-section filter comprised of R224, R225, R226, C202, C203, and C204 connects the output of the logarithmic amplifier to the input of the period amplifier and functions to filter out ripple and spurious noise. A diode shunting C203 limits negative transients.

As an operational amplifier, the control grid (point 1) of tube V25 is maintained at ground potential by feedback. The input current is given by the equation:

$$i_{in} = (C205)\ \frac{dE}{dt} = \frac{E_{out}}{(R237)}$$

or

$$E_{out} = (R237)\ (C205)\ \frac{dE}{dt}$$

Where: E = the voltage input to capacitor C205

This relationship shows that the output voltage is proportional to the first derivative in the input voltage.

The logarithmic amplifier has an output voltage proportional to the logarithm of the input current. The derivative amplifier has an output proportional to the derivative of its input. Neglecting the filter, the over-all response is given by the following equation:

$$(1) \qquad E_{out} = K_3\ \frac{d}{dt}\ (\ln i_{in})$$

Where: K_3 = a constant

If the reactor period is increasing exponentially,

$$(2) \qquad i_{in} = I_q\ e^{\frac{t}{\tau}}$$

Where: I_q = steady state or source current

t = time

τ = reactor period

$$(3) \qquad \frac{d}{dt}\ \ln\ (I_q\ e^{\frac{t}{\tau}}) = \frac{K_4}{\tau}$$

Where: K_4 = a constant

$$(4) \qquad E_{out} = \frac{K}{\tau}$$

Where: $K = K_3\ K_4$

Thus the output of the period amplifier is proportional to inverse reactor period. The output is read on meter M21 calibrated in terms of

seconds of period. Provision is made for a remote meter and a recorder connection.

When the OPERATE-CALIBRATE switch is in the CALIBRATE position, R237A is switched in as the feedback resistor reducing the gain of the period amplifier. In this position, the period alarm and period trip circuits are interlocked to assume the "safe" or tripped position.

2.2.4 Period Alarm

The period alarm is a voltage sensitive transistorized trigger circuit which operates relay K21. When the output voltage of the period amplifier is below the set trip point, transistor Q20 conducts and transistor Q21 is held in the conducting state, so that relay K21 is energized. When the period amplifier output voltage exceeds the set trip point, transistor Q20 cuts off, which forces transistor Q21 to cut off and de-energize relay K21. The action is regenerative through the common emitter connection. The form C contacts on relay K21 are available for connection to a period alarm.

Potentiometer R240A and R240B are ganged and function as the alarm adjustment. Potentiometer R241A is a calibration adjustment that brings the alarm signal within the proper span.

2.2.5 Period Trip

The period trip circuit is identical to the period alarm circuit discussed in Paragraph 2.2.4. In addition, a normal output signal of zero volts is provided. When period trip occurs, the output voltage increases to 20 volts. This signal may be used for control purposes.

SECTION III

OPERATING INSTRUCTIONS

3.1 Unpacking

Check visually, when removing the Log N Period Amplifier from its packing box, for any signs of shipping damage. Ascertain that all tubes, relays, and other components are present and secured in their proper sockets. Check connections and solder joints for possible breaks and corrosion, paying particular attention to connections on the printed circuit board. The Log N and Period Amplifier should be handled as a precision instrument.

3.2 Installation

The Log N Period Amplifier is designed for standard relay-rack mounting or table top installation. Check to ascertain that the balance of the equipment used to comprise the over-all system is compatible with the Log N Period Amplifier. The source of a-c power should be free of spurious noise for best results.

Careful shielding and grounding are important if noise-free operation is desired. Generally, it is desirable to ground the system only at the chassis of the Log N Period Amplifier, insulating the ion chamber from local ground. The low level signal cables should be isolated from the power cables to prevent pickup.

The mounting dimensions of the Log N Period Amplifiers are shown in Figures 1-1 and 1-2.

3.3 Operating Controls

3.3.1 General

The controls discussed in the following paragraphs are the only controls available to the operator of the Log N Period Amplifier. All other controls are calibration controls that are used for circuit adjustments and which are discussed under calibration procedures.

3.3.2 Power On Lamp

An indicator lamp on the right side of the front panel is lighted when power is applied to the instrument. There is no power switch. This instrument is designed for continuous operation as a reactor protective monitor and it is seldom turned off. Application of power should be controlled by a system remote-master switch.

3.3.3 Amplifier Disabled Lamp

An indication lamp in the center of the front panel is lighted when the amplifier is in the CALIBRATE position to indicate that the period amplifier is disabled and is in the safe or tripped condition.

3.3.4 Operate-Calibrate Switch

This switch, located on the left side of the front panel, has three positions: CALIB. 10^{-6}, OPERATE, and CALIB. 10^{-1}. The center OPERATE position is normal. When the switch is turned to the CALIB. 10^{-6} position, the period amplifier is disabled; the amplifier disabled lamp is lit; the signal from the ion chamber is disconnected; a calibration current of 10^{-10} amperes is introduced into the amplifier; and the LO-CAL. potentiometer is uncovered so that it may be adjusted with a screw driver from the front panel.

In a similar manner, when the switch is turned to CALIB. 10^{-1} position, a current of 10^{-5} amperes is applied and the HI-CAL. potentiometer is uncovered to permit adjustment from the front panel.

3.3.5 Log N Meter

The Log N Meter is calibrated in terms of power level from 10^{-7} to 1 in seven decades, where 1 represents full power. The meter is a General Electric type DB-18 with a 7.1 inch scale length and 250 degree rotation.

3.3.6 Period Meter

The period meter is calibrated for periods from minus 30 to plus 3 seconds. It is a General Electric type DB-18, 7.1 inches, 250 degrees scale.

3.3.7 Period Alarm Adjustment

The period alarm adjustment is a screw driver adjustment located on the top left center of the back panel with a range of plus 30 to 3 seconds, (refer to Figure 3-1).

3.3.8 Period Trip Adjustment

The period trip adjustment is a screw driver adjustment located on the top right center of the back panel with a range of plus 30 to 3 seconds.

3.4 Connections

For receptacle connections pertaining to both Catalog No. 655C910G1 and No. 655C910G2, refer to Figure 3-1.

FIGURE 3-1 LOG N AND PERIOD AMPLIFIER
REAR PANEL

3.5 Operating Procedures

1. Connect the Log N Period Amplifier into the system consisting of an ionization chamber, chamber polarizing voltage, and the Log N Period Amplifier.

2. Energize the Log N Period Amplifier and power supply and allow time for warmup.

3. Adjust the calibration at the 10^{-6} and 10^{-1} points on scale. Repeat adjustments until both points read correctly (see Calibration Procedures in Section IV).

4. Return OPERATE-CALIBRATE switch to OPERATE. The Log N Period Amplifier should now read the ion chamber current. Note: If the ion chamber current is less than 10^{-11} amperes, the meter reading will not be on scale.

3.6 Precautions

1. The line voltage should not exceed the equipment ratings.

2. All equipment used with the Log N Period Amplifier should be compatible.

3. When handled during operation, maintenance, or repair, the Log N Period Amplifier should be treated as a precision instrument.

SECTION IV

MAINTENANCE INSTRUCTIONS

4.1 General

The General Electric Log N and Period Amplifier is designed to operate with a minimum of maintenance and adjustment. The unit is balanced and calibrated at the factory and should not require additional adjustment (except for the 10^{-6} - 10^{-1} built-in calibration) unless tubes are replaced. If V20, V21, V22, or V25 are replaced, the instrument should be readjusted. Other tubes can be replaced without any effect on the calibration.

4.2 Periodic Maintenance

Routine periodic maintenance will serve to keep the General Electric Log N Period Amplifier in operation for long periods of time. If the unit is in continuous service, it should be checked every 5,000 hours. If it is in casual use only, it should be checked every 1,000 hours of operation, or at least annually.

During the routine periodic maintenance, all plug-in type tubes should be removed and checked. Do not remove or attempt to test electrometer tubes V21, V22, and V25 unless there is substantial evidence that they are causing trouble. These tubes have a long life and seldom need to be replaced unless abused. Replace all tubes that are weak or faulty with new tubes as listed in the Replaceable Parts List, Section V.

Visually inspect for any signs of loose terminals, corroded joints, or overheated parts, and brush accumulated dust from circuit boards. Be sure to replace all cover plates and all tube shields properly.

4.3 Calibration Procedure

4.3.1 Log N Amplifier

The following procedure should be used to calibrate the Log N Amplifier:

1. With the power turned off, adjust the mechanical zero on the Log N meter to read 10^{-7} and on the period meter to read infinity.

2. Turn power on and adjust R2 on power supply to indicate +20 ±0.1 volts d-c at point F.

3. Turn the OPERATE-CALIBRATE switch to calibrate 10^{-6}.

4. Adjust R263 so that the period meter again reads infinity.

5. Adjust R208 so that the Log N meter reads 10^{-6}. (R208 is on the front of the panel behind the port hole.)

6. Turn OPERATE-CALIBRATE switch to Calibrate 10^{-1}.

7. Adjust R220 so that the Log N meter reads 10^{-1}. (R220 is on the front panel.)

8. Repeat (5) and (7) until both points calibrate. If calibration cannot be achieved at this point due to running out of adjustment on the potentiometers, proceed as follows:

   a.) Return R208 to about the center of its travel.

   b.) With the OPERATE-CALIBRATE switch on 10^{-6}, adjust R209 so that the Log N meter reads 10^{-6}.

   c.) With the OPERATE-CALIBRATE switch on 10^{-1}, adjust R220 to 10^{-1}.

   d.) Repeat b.) and c.) until both points calibrate. Now R208 is in its center position ready for routine calibration.

9. Return the OPERATE-CALIBRATE switch to OPERATE. The Log N meter should read down-scale below 10^{-7} with no input current. If not, check for one of the troubles listed in 4.5.2.

4.3.2 Period Amplifier

The following procedure should be used to calibrate the period amplifier. Do not attempt to calibrate the period amplifier until the Log N Amplifier has been calibrated.

1. With the Log N meter on 10^{-1} calib., measure the voltage at point AA.

2. With the Log N meter on 10^{-6} calib., measure the voltage at point AA.

3. Subtract the voltage measured at (2) from that measured at (1) and refer to the difference as V.

4. Connect a negative going voltage ramp at point AA with its output calculated by the following formula:

$$\text{ramp (volts/sec.)} = \frac{V}{\text{Period (sec.)} \times 16.2}$$

   Where V is the voltage in (3) above.

5. With a 3-second period ramp applied, adjust R226 so that the period meter reads 3 seconds.

   Note: The period alarm and period trip adjustments are roughly calibrated by the marks on the back panel. If an exact calibration is required, continue with the following procedure:

6. Apply a ramp as in (4) equivalent to the period at which an alarm is desired. Adjust the period alarm (on back panel) so that the circuit just trips.

7. Apply a ramp as in (4) equivalent to the period at which a trip is desired. Adjust the period trip (on back panel) so that the circuit just trips.

4.4 Calibration Instruments

The following instruments are recommended to accomplish the calibration and trouble shooting procedures:

1. Function Generator, Hewlett-Packard Model HP 202A.

2. Vacuum Tube Voltmeter, Hewlett-Packard, Model HP 410B.

3. D-C Amplifier and Electrometer, General Radio, Model 1230-A.

4.5 Trouble Shooting

4.5.1 General

If the Log N and Period Amplifier does not function properly, the following procedures should be followed to localize the source of trouble:

1. Check to see that the line cord is connected to a live circuit. Verify proper power source regulation.

2. Check for a blown fuse. If a fuse is blown, determine the cause and correct any improper condition that may exist before energizing the equipment.

3. Check the unit for faulty tubes utilizing the Voltage Chart, Table 4-1, to isolate probable faulty tubes.

4. Inspect the unit for faulty parts utilizing the Voltage Chart, Table 4-1, and the etched-circuit board illustrations shown in Figures 1-3 through 1-6 for parts location.

4.5.2 Leakage Current

If the general trouble shooting procedures do not locate the circuit

TABLE 4-1

VOLTAGE CHART

LOG N AND PERIOD AMPLIFIER

TUBE	PIN NUMBER								
	1	2	3	4	5	6	7	8	9
V1	620AC	140	84	143	143	143	330	1.8	620AC
V2	135	139	139	139	302	302	135	-	-
V3	58	-0.8	0	0	0	135	-2.8	0	0
V4	66	0	7.2	0	0	63	-0.9	0	0
V5	60	-0.9	0	0	0	68	-1.0	0	0
V6	-9.7	0	0	0	143	143	9.7	-	-
V7	0.8	-148	-0.1	-148	0.73	0	-148	-	-
V20	-	-	-	-	-	-	-	-	-
V21	-	-	-	-	-	-	-	-	-
V22	-	-	-	-	-	-	-	-	-
V23	58	8.3	9.0	0	0	73	8.0	9.0	0
V24	0	-60	-59	0	0	-26	-60	-59	0
V25	-	-	-	-	-	-	-	-	-
V26	0	-53	-52	0	0	75	-2.6	0	0
V27	-	-	-	-	-	-	-	-	-

TRANSISTOR	EMITTER	BASE	COLLECTOR
Q1	0	-0.2	-10
Q2	6.5	6.4	-0.2
Q3	0	0.1	6.4
Q4	6.6	6.6	0.1
Q20	-11	-27.5	17
Q21	-11	-10.8	-11
Q22	-6.6	-22	17
Q23	-6.6	-6.3	-6.4

TABLE 4-1 (Continued)

VOLTAGE CHART

LOG N AND PERIOD AMPLIFIER

1. All voltages measured with respect to chassis ground with a 10 megohm input impedance vacuum tube voltmeter.

2. Line voltage set at 115 volts a-c, 60 cycles.

3. A dash indicates that the pin is not available for measurement or does not exist.

4. Voltages are positive d-c unless otherwise noted.

5. Allow thirty minutes warm-up before attempting measurements.

6. Allow reasonable tolerances on all measured voltages, especially grid to cathode bias readings.

fault, check the circuit for leakage current. With no input current (ion chamber cable disconnected) and the OPERATE-CALIBRATE switch on OPERATE, the Log N meter, properly calibrated, should read down-scale below 10^{-7}. If the meter does not read down-scale, investigate one of the following causes and remedy as required:

1. Dirty Insulators - Accumulated dust and fingerprints on the insulators create paths for leakage currents. The leakage resistance (insulation resistance) is measured from the top of the insulator to ground. Before making the measurement, turn off power, remove tube V20 from its socket, and disconnect the G1 grid lead from electrometer tube V21. Remove the lead from the stand-off insulator located in the electrometer tube compartment. If the measured resistance is substantially less than 10^{13} ohms, clean the switch assembly, V20 socket assembly, and the stand-off insulator with trichlorethylene.

2. Faulty Diode V20 - Measure the resistance of the diode from plate to cathode. If this is less than 5×10^{11} ohms and cannot be improved by cleaning, replace with a new diode. (See Section 4.5.3 on aging diodes.)

3. Leaky Capacitor C200A - Measure the resistance of capacitor C200A and replace if less than 10^{13} ohms.

4. Grid Current - Grid current in electrometer tube V21 can cause an up-scale reading. If steps 1, 2, and 3 above do not clear the trouble, replace electrometer tube V21.

4.5.3 Diode Aging V20

If V20 is replaced by a new diode, there may be a tendency to drift for the first 24 hours of operation. If this drift is objectionable, diodes can be pre-aged by operating them with a filament voltage of 5.5 volts and a plate current of 10 microamperes for 50 hours before installation.

4.5.4 Restoration of Circuit Operation

If the Log N and Period Amplifier does not operate properly, it is usually due to the failure of a single component. To restore proper operation, locate the faulty component(s) and replace it with a like serviceable item. Do not make compensating changes in other parts of the circuit to restore operation. To do so affects the design and may cause inferior performance of the unit. Section V contains a list of specifications on Replaceable Parts.

4.5.5 Printed Circuit Board Repair

Use extreme care in removing and replacing components soldered to the printed circuit board. Excessive heat will damage the bond between the epoxy base material and the conducting material. If possible,

remove the component by applying heat to its leads and not to the circuit board. A small soldering iron such as General Electric 6A212 with transformer 6A362G2, is recommended for this type of operation.

If conducting material is accidently dislodged from the board, it may be replaced with any high quality plastic cement. To repair extensive damage such as might occur by using a high wattage soldering iron, the use of a printed circuit repair kit is recommended, such as the Walsco No. 13-K or the General Cement No. 680.

SECTION V

REPLACEABLE PARTS LIST

Circuit Reference	Description	*Mfr's. Code Letter Mfr's. Designation
C1, C2	Capacitor, Electrolytic Dual 5 MFD, 600 V	GE 111A2299P1
C3	Capacitor, Electrolytic 750 MFD, 50 V	SP SP-CE41F751G
C4	Capacitor, Electrolytic 750 MFD, 25 V	SP SP-CE64F750F
C5	Capacitor, Electrolytic 75 MFD, 25 V	SP SP-CE62F750F
C6, C7, C10, C11, C12	Capacitor 0.01 MFD, 500 V	CD 1A5S1
C8	Capacitor 1 MFD, 400 V	HE 91Q4105
C9	Capacitor 0.02 MFD, 400 V	HE 91Q4203
C13	Capacitor 0.03 MFD, 500 V	CD 1AD5S3
C14	Capacitor 0.003 MFD, 500 V	CD 1R5D3
C200A	Capacitor 0.00051 MFD ± 5%, 5 V	CG CY15C511J
C200, C201	Capacitor 0.000051 MFD, 250 V	CD 22R5Q51
C202, C203, C204	Capacitor 1 MFD, 200 V	HE 91Q2105
C205	Capacitor 1.75 MFD ± 5%, 300 V	HE 9D1Q
C206	Capacitor 0.00024 MFD, 500 V	CD 22A5T24

Circuit Reference	Description	*Mfr's. Code Letter Mfr's. Designation
C207	Capacitor 0.2 MFD, 200 V	HE 91Q2204
R1	Potentiometer 250 ohm, 2 W	O CLU2511
R2	Potentiometer 10,000 ohm, 2 W	CL 43C2-10K
R3	Resistor 100 ohms ± 10%, 1 W	AB GB1011
R4, R7, R10, R14, R17, R20	Resistor 100,000 ohms ± 10%, 1/2 W	AB EB1041
R5, R8, R16, R19, R22, R234	Resistor 1,500,000 ohm ± 10%, 1/2 W	AB EB1551
R6, R9, R15, R18, R21	Resistor 680,000 ohms ± 10%, 1/2 W	AB EB6841
R11, R12, R233	Resistor 1,000,000 ohm ± 10%, 1/2 W	AB EB1051
R13, R235	Resistor 15,000 ohm ± 10%, 2 W	AB HB1531
R23	Resistor 15,000 ohm ± 10%, 5 W	WL 5X15000
R24, R25	Resistor 1600 ohm ± 5%, 1/2 W	AB EB1625
R26, R29	Resistor 470 ohm ± 10%, 1/2 W	AB EB4711
R27	Resistor 24,000 ohm ± 10%, 1/2 W	AB EB2421
R28	Resistor 1000 ohm ± 10%, 1/2 W	AB EB1021
R30	Resistor 560 ohm ± 10%, 1/2 W	AB EB5611
R31, R221, R224, R225, R226	Resistor 10,000 ohm ± 10%, 1/2 W	AB EB1031
R32	Resistor 5100 ohms ± 10%, 1/2 W	AB EB5125

Circuit Reference	Description	*Mfr's. Code Letter Mfr's. Designation
R200	Resistor, Hi-Meg 2.2×10^{11} ohm ± 10%, 1/2 W	VI Hi-Meg
R201	Resistor, Precision 2,200,000 ohms ± 1%, 1/2 W	IRC DCC
R202, R212, R213	Resistor 10,000,000 ohms ± 5%, 1/2 W	AB EB1065
R203, R204, R205, R206, R227, R228	Resistor 22,000,000 ohms ± 5%, 1/2 W	AB EB2265
R207	Resistor 510,000 ohms ± 5%, 1/2 W	AB EB5145
R208, R209	Potentiometer 25,000 ohm, 2 W	O CLU2531
R210, R211	Resistor 470,000 ohms ± 5%, 1/2 W	AB EB4745
R214, R215, R229	Resistor 6,800,000 ohms ± 5%, 1/2 W	AB EB6855
R216	Resistor 15,000 ohms ± 10%, 1 W	AB GB1531
R217, R218	Resistor 51,000 ohms ± 5%, 1 W	AB GB5135
R219	Resistor 3000 ohm ± 5%, 1/2 W	AB EB3025
R220	Potentiometer 1000 ohm, 2 W	O CLU1021
R222	Potentiometer 2500 ohm, 2 W	O CLU2521
R223	Resistor, Precision 1200 ohms ± 1%, 1/4 W	H H-10
R230	Resistor, Hi-Meg 100,000,000 ohms ± 5%	VI Hi-Meg
R232	Resistor 820 ohms ± 10%, 1/2 W	AB EB8211
R236	Resistor 10,000 ohms ± 10%, 2 W	AB HB1031

Circuit Reference	Description	*Mfr's. Code Letter Mfr's. Designation
R237	Resistor, Hi-Meg 10^9 ohm ± 1%	VI Hi-Meg
R238, R250	Resistor, Precision 50,000 ohm ± 1%, 1/2 W	IRC DCC
R239	Resistor 220,000 ohm ± 5%, 1/2 W	AB EB2245
R240, R251	Potentiometer, Dual 100,000 ohm 2 W	CL D53C2-100K-Y
R241, R241A	Potentiometer 5000 ohm, 2 W	O CLU5021
R243, R254	Resistor 2700 ohms ± 5%, 1/2 W	AB EB2725
R244, R255	Resistor 5100 ohms ± 5%, 1/2 W	AB EB5125
R246, R257	Resistor 51,000 ohms ± 5%, 1/2 W	AB EB5135
R247, R258	Resistor 2,200,000 ohms ± 5%, 1/2 W	AB EB2255
R248, R259	Resistor 18,000 ohms ± 5%, 2 W	AB HB1835
R260	Resistor 10,000 ohms ± 5%, 1/2 W	AB EB1035
R261	Resistor 100 ohms ± 10%, 1/2 W	AB EB1011
R262	Resistor 51 ohms ± 5%, 1/2 W	AB EB5105
R263	Potentiometer 250 ohms "U" Taper	AB Type 6
R264, R265	Resistor, Precision 10 ohms ± 1/2 %, 1/4 W	H H-10
R266	Resistor 560 ohms ± 5%, 1 W	AB GB5615
R267	Resistor 100 ohms 2 W	WL 5X100

Circuit Reference	Description	*Mfr's. Code Letter Mfr's. Designation
R270	Resistor 1200 ohms ± 5%, 1/2 W	AB EB1225
CR1, CR2	Diode	GE IN440
CR3, CR4	Diode, Zerner	RCI 1Z15
CR23	Diode	GE 1N91
Q1	Transistor	MH 2N539A
Q2, Q4	Transistor	GE 2N43
Q3, Q20, Q21, Q22, Q23	Transistor	GE 2N167
V1	Vacuum Tube	GE 6203
V2, V6	Vacuum Tube	GE 6005
V3, V4, V5	Vacuum Tube	GE 6201
V7	Vacuum Tube	GE 0A2
V20	Vacuum Tube	GE 9004
V21, V22, V25	Vacuum Tube	GE 5886
V23	Vacuum Tube	GE 5751
V24, V26	Vacuum Tube	GE 6922
V27	Vacuum Tube	GE 5787
DS121	Indicating Lamp	ID 1010-A4

Circuit Reference	Description	*Mfr's. Code Letter Mfr's. Designation
DS1	Indicating Lamp	D 101-5030-931
F1	Fuse, 5 Amp.	L 312005
K20, K21	Relay 5000 ohm Coil	PB PW5LS
L1	Choke 15 Henry	GE 111A1732P1
T1	Power Transformer	GE 856B162P1

MANUFACTURER'S CODE LETTERS

CODE	MANUFACTURER
AB	Allen-Bradley 136 W. Greenfield Ave. Milwaukee 4, Wisconsin
CD	Cornell-Dubilier 333 Hamilton Boulevard South Plainfield, N. J.
CG	Corning Glass 95-6 Crystal Street Corning, New York
CL	Clarostat Mfg. Co. Washington Street Dover, New Hampshire
D	Dialco Corporation 60 Stewart Avenue Brooklyn, New York
GE	General Electric 2151 South First St. San Jose, California
H	Hycor 11423 Vanowen St. No. Hollywood, California
HE	Hopkins Engineering Co. 12900 Foothill Boulevard San Fernando, California
ID	Industrial Devices Edgewater, New York
IRC	International Resistor Corp. 401 No. Broad Street Philadelphia, Pa.
L	Littlefuse 1865 Miner St. Des Plaines, Illinois
MH	Minneapolis Honeywell 2753 4th Avenue Minneapolis, Minn.

CODE	MANUFACTURER
O	Ohmite 3601 W. Howard St. Skokie, Illinois
PB	Potter-Brumfield 1200 E. Broadway Princetown, Indiana
RCI	International Rectifier Corp. 1521 E. Grand Avenue El Segundo, California
SP	Sprague Electric Co. Marshall Street North Adams, Mass.
VI	Victoreen Instrument 5806 Hough Ave. Cleveland, Ohio
WL	Ward-Leonard Electric Co. Mt. Vernon, New York

MP MASTER
MA32631